Curriculum Development

Renewing the Sustainable Energy Curriculum – Curriculum Frameworks and Guidance for Course Delivery

Sustainable Energy Knowledge and Generic Attributes Taxonomy Supporting Document

Explanation and presentation of the sustainable energy knowledge and generic attributes taxonomies developed for the sustainable energy curriculum maps
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Section 1 – Introduction
**INTRODUCTION**

This Sustainable Energy Curriculum Frameworks Knowledge Taxonomy Supporting Document has been produced to provide details and explanation of the sustainable energy “knowledge taxonomies” developed to support the development of the Sustainable Energy Curriculum Frameworks.

“Curriculum renewal in higher education can be difficult, time-consuming, and arduous, but the payoff is a curriculum that is current, responsive, proactive and effective.” (ALTC Good Practice Report: Curriculum Renewal, Narayan and Edwards, 2011).

Ongoing curriculum renewal is more difficult but vital for multidisciplinary courses preparing graduates to work in a specialized rapidly changing field. After more than 15 years of offering tertiary level “sustainable energy” qualifications in Australian Universities there was a clear need to assess how these courses are taught and develop curriculum frameworks to guide Universities designing/redesigning programs and courses to provide graduates with the relevant skills, knowledge and attributes (capabilities) seen by graduates and employers as required to work in this rapidly changing field.

This document is a companion and supporting document to the “Renewing the Sustainable Energy Curriculum – Curriculum Frameworks and Guidance for Course Delivery Curriculum Frameworks Guide” developed by the “Renewing the sustainable energy curriculum – providing internationally relevant skills for a carbon constrained economy” project. This document presents and explains the associated “Knowledge Taxonomies” which were used to develop the sustainable energy curriculum frameworks. These two documents are available from the project website - <http://www.murdoch.edu.au/projects/secfp/>.

The project was led by Murdoch University and brought together a team of academics from four other Australian Universities that have recognised courses or programs in sustainable energy to develop a set of curriculum frameworks for tertiary level sustainable energy programs. The project also sought to provide guidance relating to a number of key questions related to the design and delivery of the resulting programs and courses. The collaborators included The Australian National University, Queensland University of Technology, Murdoch University, The University of New South Wales and the University of South Australia.

**Note:** This document should always be used in conjunction with the “Renewing the Sustainable Energy Curriculum – Curriculum Frameworks and Guidance for Course Delivery Curriculum Frameworks Guide”.

The main aim of the project was to scope and develop sustainable energy curriculum frameworks for Australian higher education Institutions that meet the needs of Australian and international student graduates and employers, both now and into the near future. This included:

- Developing a list of sustainable energy skills, knowledge and generic graduate attributes required by employers, which were then formulated into curriculum frameworks.

As well as developing the curriculum frameworks the project also aimed to gain an understanding of 5 key questions related to program design and course delivery including:

1. The mixture of inter/multi-disciplinary content vs specialized content that should be included in sustainable energy programs. For example how much and what type of policy and “enablers” content should be included as core content in sustainable engineering degrees and alternatively what type of technical knowledge should be included as core content in humanities courses with a focus on policy and enablers?
2. Whether Universities should develop and offer specialist courses and programs (e.g. BEng in Sustainable Energy) at undergraduate level versus embedding the relevant skills and knowledge into existing discipline training such as an existing Electrical Engineering or Power Engineering degree;
3. The feasibility and desirability of providing sustainable energy teaching by face-to-face mode only versus online and flexible delivery;
4. The need for and amount of work integrated learning that is optimal, or acceptable during sustainable energy degrees and what type and level of involvement industry practitioners should have in the delivery of the courses; and
5. The need for and how to enable sufficient internationalisation of the curriculum and course content so that it meets the needs of international students studying in Australia or at affiliated international institutions and Australian graduates seeking to work overseas.

The curriculum frameworks are designed to be relevant to specialist sustainable energy engineering and energy studies programs, as well as conventional engineering, science and humanities programs which have a sustainable energy focus or major. The research based approach used to develop the curriculum frameworks and the role of the knowledge taxonomies in this is described in more detail in Section 3:

The finalised project materials and publications, including this one, are available from the project website - <http://www.murdoch.edu.au/projects/secfp/>. The website also contains a list of sustainable energy programs offered in Australian Universities.
Section 2 – The Knowledge and Generic Attributes Taxonomies
Knowledge Taxonomies

Knowledge taxonomies are a key part of developing the sustainable energy curriculum frameworks for Sustainable Energy programs in Australian Universities.

Curriculum frameworks have been developed for sustainable energy programs or qualifications at different levels within the Australian Qualifications Framework (AQF). In order to develop these curriculum frameworks the curriculum development framework of Dowling and Hadgraft [2013] was adapted and extended as discussed in detail in Section 3. Part of this new approach and process was to develop a set of sustainable energy knowledge taxonomies that graphically present the knowledge and knowledge linkages needed by sustainable energy graduates.

The knowledge taxonomies present in a visual manner the knowledge required by sustainable energy graduates and the linkages between different knowledge areas. These knowledge taxonomies correspond to the technical capabilities side of the Dowling and Hadgraft [2013] capability cube. The knowledge grouped in six branches of sustainable energy knowledge and one branch of generic and discipline specific knowledge/capabilities. These knowledge taxonomies are the start of the curriculum framework development approach and from these the “Capability Cloths” were then developed. The knowledge taxonomies define what is meant by sustainable energy and provide a clear way to navigate and link the different knowledge required for this complex multi-disciplinary area.

Based on industry experience, research for the project and project team workshops the emerging role and area of “Carbon Management” was identified as a new distinct role and therefore this knowledge area was included in the knowledge taxonomies. Although this is an overarching role, of which sustainable energy is a substantial, but not the only part it has been included in the project for two reasons:

1. There is a very large amount of overlap between the carbon management and the three “sustainable energy” specialisation areas.
2. There is no other field with which this emerging area can be better associated.

One of the key aspects of the postgraduate curriculum frameworks is that each of the four areas of specialisation has its specific set of prerequisites and discipline specific capabilities that need to be attained before graduating in that specialisation. This has not been explicitly spelt out in existing programs and provides a clear understanding for students who have trained at Undergraduate level in a different discipline whether they can realistically train for
a specific area, or what additional capabilities they may need to acquire in order to work in that area. Generic attributes and professional skills are an underpinning capability set for all of the specialisations and so are included in all of the curriculum frameworks. In light of this a Generic and Discipline Specific Capabilities taxonomy diagram was developed showing and linking the generic attributes and specific capabilities of four discipline areas:

- Engineering graduate;
- Science and technology graduate;
- Humanities and Social Science graduate; and
- Business graduate.

Figure 1 shows the overarching knowledge taxonomy with the 7 main areas of sustainable energy knowledge. Each of these 7 areas has a set of sub taxonomies that describe in more detail the knowledge required for that area.

The Sustainable Energy knowledge taxonomies and Generic and Discipline Specific capabilities taxonomies are presented in the following section by area. The next section also presents a generic guide to interpreting and using the sustainable taxonomies.
Figure 1: Overarching sustainable energy knowledge taxonomy
How to Use the Knowledge Taxonomies

This section describes how to interpret and use each set of the sustainable energy knowledge taxonomies.

There are knowledge sub taxonomies for each of the seven areas in the overarching knowledge taxonomy shown in Figure 1 above.

Figure 2 shows how the overarching knowledge taxonomy (shown in Figure 1) relates to the sub taxonomies.

Figure 2: Relationship between the overarching sustainable energy knowledge taxonomy and the individual sub taxonomies.

Figure 3 shows a typical sub taxonomy for a particular knowledge area. This shows the more detailed knowledge required in this area and the relationship or linkage to other knowledge.
Figure 3: Typical individual knowledge taxonomy – Established new renewable energy generation.
Knowledge Taxonomy Set 1: Renewable Energy Systems

These knowledge taxonomies provide information about the sustainable energy knowledge required in the area of power generation - renewable energy.
Knowledge Taxonomy: Power generation technologies – Conventional renewable energy

Power Generation Technologies – Established Conventional Sub Taxonomy

Hydropower
- Electrical
- Mechanical
- Large scale
- Small scale/micro
- Resource assessment
- Component design and manufacture
- System design & installation
- Network integration

Bioenergy
- Combustion
- Gasification/Pyrolysis
- Human refuse/garbage
- Stoves
- Furnace
- Sewage gas
- Algae
- Landfill gas
- Solid combustion
- Biofuels
- Biofuels
- Waste vegetable oil
- Waste animal oils and fats
- Grains (E.g. canola/soy)
- Tree nuts (E.g. palm oil)

Conventional Geothermal
- Resource assessment
- Component design and manufacture
- System design & installation
- Network integration
- Thermal
- Electrical
- Large scale
- Small scale/micro
Knowledge Taxonomy: Power generation technologies – Established new renewable energy

Power Generation Technologies – Established New Sub Taxonomy

- Solar PV
  - Large scale
  - Small to medium scale
  - Resource assessment
  - Component design and manufacture
  - Solar PV farm design
  - System design and installation
  - Network integration
  - Building integrated PV
  - Free standing
  - Grid connected
  - Off-grid

- Solar Thermal
  - Large scale
  - Small to medium scale
  - Resource assessment
  - Component design and manufacture
  - Solar thermal power station design
  - System design and installation
  - Network integration
  - Building integrated

- Wind
  - Large scale
  - Small to medium scale
  - Resource assessment
  - Component design and manufacture
  - Offshore
  - Wind farm design
  - Onshore
  - System design & installation
  - Network integration
  - Building integrated wind
  - Free standing
  - Grid connected
  - Off-grid

- Hybrid RE Systems
  - Resource assessment
  - Component design and manufacture
  - System design and installation
  - Mini-grid integration including storage
  - Grid connected
  - Off-grid
Knowledge Taxonomy: Power generation technologies – Emerging renewable energy

Power Generation Technologies - Emerging Sub Taxonomy

- Wave
  - Resource assessment
  - Materials and components manufacture
  - System design and construction
  - Grid integration

- Tidal

- OTEC/Osmotic

- Hot Rock Geothermal
  - Resource assessment
  - Materials and components manufacture
  - System design and construction
  - Grid integration
  - Geology and drilling
Knowledge Taxonomies Set 2: Energy Efficiency

These knowledge taxonomies provide information about the sustainable energy knowledge required in the area of energy efficiency.
Knowledge Taxonomies Set 3: Policy and Enablers

This knowledge taxonomy provides information about the sustainable energy knowledge required in the area of policy and enablers.
Knowledge Taxonomy: Policy and enablers

Enablers Sub Taxonomy

**Economics**
- Economic concepts
- Structure of energy supply systems
- Regulation & open access in the energy sector
- Energy markets
- Externalities in energy supply
- Investment decision making techniques & cost benefit analysis
- Taxation
- Economics of nuclear power
- Economics of renewable energy
- Resource economics, environmental macroeconomics & thermodynamics

**Policy**
- Policy analysis
- Game theory & energy policy formulation
- Public choice theory & policy decisions
- Policy institutions
- Policy instruments
- Policy interactions
- Energy policy in the global environment
- Energy security
- Efficiency in the energy sector
- Energy safety & risk assessment
- Energy & environmental protection
- Electricity market reform

**RD&D (including Financing)**
- Training & Capacity Building
- Environmental & Social Impacts
- Stakeholder Engagement & Behaviour Change
- Standards
- Sustainable Energy Project and Business Management
- Climate & Energy Law
Knowledge Taxonomies Set 4:
Carbon Management

This knowledge taxonomy provides information about the sustainable energy knowledge required in the area of carbon management.
Knowledge Taxonomy Set 5:
Electricity Transmission, Storage and Networks

This knowledge taxonomy provides information about the sustainable energy knowledge required in the area of electricity transmission, storage and networks.
Knowledge Taxonomy: Electricity transmission, storage and networks

Electricity Transmission, Storage and Network Systems Sub Taxonomy

- Thermal Storage
  - Molten salt
  - Ice/cold storage
  - Phase change materials
  - Concrete/rock/water (sensible heat)
  - Ceramics (sensible heat)
  - Flashing steam

- Physical Storage
  - Kinetic energy
  - Potential energy
  - Flywheels
  - Pumped hydro
  - Compressed air

- Chemical Storage
  - Thermochemical
  - Electrochemical
  - Ammonia splitting/reformation
  - Methane splitting/reformation
  - Batteries
  - Low temperature
  - High temperature
  - Flow
  - Hydrogen
  - Electrolysis
  - Storage
  - Fuel cells

- Power Quality and Grid Integration
  - Transmission and power electronics
  - Power quality and control electronics
  - Inverters
  - Transmission
  - AC
  - DC
  - Load control/demand side management

- Direct Electric Storage
  - Operation and management
  - Resources and demand forecasting
  - Penetration, stability, and control
  - Superconducting magnetic energy storage
  - Super capacitors

- Smart Grids
This knowledge taxonomy provides information about the sustainable energy knowledge required in the area of energy solutions for developing countries.
Knowledge Taxonomy: Energy solutions for developing countries

Energy Solutions for Developing Countries Sub Taxonomy

- Improved use of Traditional Energy Uses
  - Human and animal power
  - Fuelwood and charcoal
  - Crop residues

- Renewable Energy Sources
  - Small scale renewable energy systems
  - Electrification using solar
  - Cooking with renewable energy
  - Wind and water power

- Sustainable Transport and Biofuels

- Sustainable Development and Enablers
  - Successful implementation of renewable energy
  - Technology selection, transfer and gender issues
  - Markets, microfinance and project planning
Knowledge Taxonomy Set 7:
Sustainable Transport

These knowledge taxonomies provide information about the sustainable energy knowledge required in the area of sustainable transport.
Knowledge Taxonomy: Sustainable transport – Alternative fuels

Sustainable Transport Alternative Fuels Sub Taxonomy

Biofuels
- Conventional (1st Generation)
  - Feedstock analysis
  - Oil crops
  - Transestertification
- Emerging (2nd / 3rd Generation)
  - Biodiesel
  - Sugar based hydrocarbons
  - Microalgae
  - Biocarbons to liquids (BL)
  - Hydrotreated vegetable oil

Hydrogen
- Conventional
  - Centralised natural gas reforming
  - Centralised electrolysis
  - Coal gasification
- Emerging
  - Bioprecess (e.g. biorefineries)
  - On-site electrolysis
  - Carbon Black and Hydrogen (GabH)

Enablers
- On-site reforming
- Electrolysis
- CO2 sequestration
- Thermocatalytic cycles
- Biological (e.g. photoelectrochemical)
- Photoelectrochemical
- Social-economic impacts (e.g. food vs energy security)
- Environmental impacts
- LCA & systems analysis
- Policy & legislation
- Risk management

Technology and Systems
- See associated diagram

*Internal combustion engine

Other
- Biochar
- Methane
- Dimethyl ether (DME)
- Pyrolysis based fuels
- Nitrile fuels (e.g. furane)
- Hydrogen gas turbines
- Hydrogen ICE

Use
- Combustion
- Electric

Storage
- Liquid hydrogen transport containers
- Liquid hydrogen storage
- Boron Hydrides
- Activated carbon
- Adsorbers

Distribution
- Hydrogen liquefaction
- Liquid hydrogen trailer
- Stationary

Production
- Hydrogen production
- Hydrogen liquefaction
- Compressed gaseous hydrogen trailer
- Compressed gaseous hydrogen tank

Technology and Systems
- See associated diagram
In order to develop curriculum frameworks for the range of multidisciplinary areas in which sustainable energy graduates work the approach in the Dowling and Hadgraft [2013] was modified to develop and differentiate a set of “generic” and “discipline” capabilities required by graduates. These generic (also known as generic attributes) and discipline specific capabilities were organised and presented in a taxonomy diagram similar to the knowledge taxonomies. In order to cover the range of roles potentially undertaken by sustainable energy graduates, as well as the generic capabilities (or attributes) required by all University graduates four sets of discipline specific capabilities were identified and mapped to the three conventional discipline areas in the sustainable energy capability cloths: Engineering; multidisciplinary/technical; and a combined humanities and social sciences and business. The capabilities were derived from existing generic and discipline capability/attributes lists published by Universities.

The generic attributes and discipline specific capabilities taxonomy is presented in the following figure.
Generic Attributes and Discipline Specific Capabilities

Generic Skills and Professional Attributes

Generic University Graduate

Engineering Graduate
- Personal commitment
  - Ethics
  - Competency
  - Responsibility
  - Obligation to Community
    - Safe & sustainable solutions
    - Community & stakeholder engagement
      - Identify, assess & manage risks
      - Laws and regulations
      - Value in the Workplace
        - Technical Proficiency
          - Advanced knowledge
          - Local knowledge
          - Problem analysis
          - Creativity and innovation
          - Evaluation

Science and Technology Graduate
- Discipline knowledge
  - Maths, physics & chemistry
  - IT & laboratory skills
  - Technical mgmt
- Scientific research & inquiry (quantitative)
- Analytical thinking
- Judgement
- Taking action
- Performance

Humanities & Social Sciences Graduate
- Discipline knowledge
  - Governance & social responsibility
  - Public policy (design, analysis & evaluation)
  - Behaviour change
  - Stakeholder engagement & change management
  - Social & environmental impact & evaluation
- Social research & inquiry (qualitative)

Business Graduate
- Discipline knowledge
  - Business knowledge
  - Professional skills
  - Business analysis & problem solving
  - Business leadership

Global perspective

Communication
Teamwork & collaboration
Global perspectives
Information literacy
Personal & intellectual autonomy
Ethical, social & professional understanding
Section 3 – Approach and Methodology for Developing the Knowledge Taxonomies and Their Incorporation into the Curriculum Frameworks
This section describes the approach and methodology used to develop the sustainable energy frameworks and the role of the knowledge taxonomies.

**Methodology and Approach**

“Following a quality assurance model, curriculum design and change should be a combined effort of teaching staff, administrators, researchers, students and potential employers. Involvement of all stakeholders in the renewal process can produce an end result that is vital, practical and prepares graduates for immediate entry into a competitive workforce”


In order to develop the final curriculum frameworks the project adapted and extended the approach of Dowling and Hadgraft [March 2013] used by them for Environmental Engineering degrees and established curriculum mapping approaches (such as that promoted by the University of West Florida - see http://uwf.edu/eutla/curriculum_map_graduate_ALP.cfm). The key elements of the approach to developing the final curriculum frameworks is summarised in the following figure.

_Figure 7: Schematic showing the framework, approach and process for developing the sustainable energy curriculum frameworks._

The following section describes in detail the research based approach and techniques that were used to achieve the project outcomes.
Determining what knowledge and skills are required

The first step in developing the curriculum frameworks was to develop an understanding of the knowledge (called technical capabilities by Dowling and Hadgraft), skills (called process capabilities by Dowling and Hadgraft) and the generic and discipline specific capabilities required by sustainable energy graduates working in the range of roles required by industry. These then needed to be presented in a manner that could be easily understood and commented on by industry and graduates. Research was undertaken to derive a catalogue of knowledge and skills taught in existing Australian and international sustainable energy programs and courses as well as relevant sustainable energy skills reports. This included an extensive list of learning outcomes and objectives covering a wide range of knowledge and skills. Based on this research, the industry experience of the senior researcher and a workshop involving the project team members a set of sustainable energy “knowledge taxonomies” were developed. These taxonomies visually present in a diagrammatic form the range of knowledge areas considered to constitute “sustainable energy” and their relationship to each other. The overarching taxonomy diagram developed (Figure 8) shows 7 main areas of sustainable energy knowledge. Each of these areas then has a set of sub taxonomy diagrams presenting the knowledge required in more detail. Figure 9 shows the relationship between the overarching taxonomy and the sub taxonomies, while Figure 10 shows an example of a sub taxonomy. The full sets of knowledge taxonomies with accompanying narrative are available from the project website <http://www.murdoch.edu.au/projects/secfp/>.

Figure 8: Overarching sustainable energy knowledge taxonomy diagram showing the 7 main knowledge areas.
Extending the framework and approach of Dowling and Hadgraft [March 2013], a set of draft skills and knowledge (or capability) “cloths” were developed. These cloths correspond to the process capabilities and technical capabilities sides of the Dowling and Hadgraft capability cube. The cloths present in a visual manner the type (core or elective) and level (introductory, medium or advanced) of knowledge required as horizontal bars and the types of skills required as vertical bars. Figure 11 shows the overarching capability cloth. Figure 12 shows the relationship of the overarching capability cloth to the sub cloths. Figure 13 shows a typical capability sub cloth, in this case for Conventional and Established Renewable Energy Generation.
**Figure 11:** Overarching skills and knowledge cloth showing depth of knowledge for various sustainable energy areas for different discipline and role types.

**Figure 12:** Relationship of the overarching capability cloth to the sub cloths.
Figure 13: Example capabilities cloth – established renewable energy generation.

Figure 14 shows how to interpret the capability sub cloths. The skills are grouped in three conventional discipline areas (engineering, multidisciplinary/technical and business, humanities and social sciences) corresponding to the types or roles (shown on the bottom axis of the cloths) graduates are known to undertake. The colour shading (dark or light) of the horizontal knowledge bars shows whether the knowledge area is considered core (essential) or elective (required) and the thickness of the horizontal bars (thin, medium or thick) indicates the level (introductory, medium or advanced) of that knowledge.

Figure 14: Explanation of major components of a typical capability sub cloth map using the example of the energy efficiency specialization.
There are seven sets of capability cloths, corresponding to the seven main sustainable energy knowledge areas in the taxonomy. These cloths are the core of the approach and enabled a framework for engaging with graduates and industry representatives about the type and depth of capabilities required by graduates. The full set of “skills and knowledge cloths” with accompanying narrative are available from the project website <http://www.murdoch.edu.au/projects/secfp/>.

In order to develop curriculum frameworks for the programs corresponding to range of multidisciplinary areas in which sustainable energy graduates work the approach in the Dowling and Hadgraft [2013] was modified to develop and differentiate a set of “generic” and “discipline” capabilities required by graduates. These generic (also known as generic attributes) and discipline specific capabilities were organised and presented in a taxonomy diagram similar to the knowledge taxonomies. In order to cover the range of roles potentially undertaken by sustainable energy graduates, as well as the generic capabilities (or attributes) required by all University graduates four sets of discipline specific capabilities were identified and mapped to the three conventional sustainable energy discipline areas in the capability cloths: Engineering; multidisciplinary/technical; and a combined humanities and social sciences and business. The capabilities were derived from existing generic and discipline capability/attributes lists published by Universities. The generic and (4) discipline specific capability taxonomy diagram is shown in Figure 15.

Ensuring the outcomes are relevant to industry

In order to ensure the curriculum frameworks led to programs and courses that train graduates with the knowledge and skills relevant to industry it was essential to have significant graduate and industry representative input. An online survey instrument (with some responder initiated follow up interviews) was used to validate and calibrate the draft capability cloths. The surveys developed by the project team were coded and administered online using Murdoch University’s well developed online survey system. Separate surveys were used to acquire the response of graduates and those of the employers/industry representatives. Graduates were recruited by email by project team members at each member university based on contact details from alumni and graduate lists. Industry representative recruitment was done through key Industry associations who promoted the project and survey to their members by email and newsletter. The online surveys also sought background
information regarding the area of the industry in which they worked, the type of role they had and their responses regarding the 5 key questions about delivering the knowledge and skills. In light of the analysis of the detailed responses to the surveys (examples shown in Figures 16 and 17) the capability cloths were revised (calibrated).

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<td>33%</td>
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<tr>
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<td>7%</td>
<td>28%</td>
<td>19%</td>
<td>46%</td>
</tr>
<tr>
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<td>Eng.</td>
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<td>13%</td>
<td>27%</td>
<td>37%</td>
<td>23%</td>
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<tr>
<td></td>
<td>Multi.</td>
<td>17</td>
<td>13%</td>
<td>31%</td>
<td>44%</td>
<td>12%</td>
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<tr>
<td></td>
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<td>11%</td>
<td>26%</td>
<td>39%</td>
<td>24%</td>
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<tr>
<td>Enablers (Policy, Economics etc.)</td>
<td>Eng.</td>
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<td>42%</td>
<td>32%</td>
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<td>Multi.</td>
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<td>6%</td>
<td>0%</td>
<td>44%</td>
<td>50%</td>
</tr>
<tr>
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<td>All</td>
<td>64</td>
<td>9%</td>
<td>15%</td>
<td>40%</td>
<td>36%</td>
</tr>
</tbody>
</table>

Figure 16: Results of the graduate survey showing which of the 7 knowledge taxonomies were considered by them to be the most important for graduates to know.

<table>
<thead>
<tr>
<th>Degree type</th>
<th>N</th>
<th>Need for inclusion</th>
<th>Core or Elective</th>
<th>Coverage rating</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Not needed</td>
<td>Essential</td>
<td>Core</td>
<td>Elective</td>
</tr>
</tbody>
</table>

Power Generation Technologies - Established Renewables
Eng. 24 Essential 94% Core 90% Elective 80% Extensive 75%
Multi. 11 Essential 101% Core 100% Elective 95% Extensive 70%

Solar PV
Eng. 24 Essential 99% Core 90% Elective 85% Extensive 70%
Multi. 11 Essential 91% Core 90% Elective 85% Extensive 70%

Solar Thermal
Eng. 24 Essential 75% Core 65% Elective 55% Extensive 65%
Multi. 11 Essential 65% Core 60% Elective 55% Extensive 70%

Wind
Eng. 24 Essential 75% Core 50% Elective 45% Extensive 70%
Multi. 11 Essential 65% Core 65% Elective 55% Extensive 55%

Hydropower
Eng. 24 Essential 55% Core 55% Elective 50% Extensive 50%
Multi. 11 Essential 55% Core 55% Elective 55% Extensive 50%

Hydro Geothermal
Eng. 24 Needed 60% Elective 55% SomeMedium 33%
Multi. 11 Needed 60% Elective 55% SomeMedium 33%

Bioenergy (including Waste to Energy)
Eng. 24 Essential 55% Core 60% Elective 50% Extensive 55%
Multi. 11 Essential 65% Elective 65% SomeMedium 45%

Figure 17: Example of the results of the graduate survey used to calibrate and finalise the capability cloths.

Mapping the curriculum frameworks

The sustainable energy knowledge and skills and the generic and discipline specific capabilities were
mapped into a set of draft curriculum frameworks for the relevant types and level of qualifications in the AQF that are typically offered by Universities. After identifying the types and levels of degree/qualification that correspond to the three discipline areas in the capability cloths, and feedback from graduates, a curriculum mapping approach similar that used by the University of West Florida and other Universities was used (see for example <http://uwf.edu/cutla/curriculum_map_graduate_ALP.cfm>). Five sets of curriculum frameworks have been developed for sustainable energy programs/qualifications including:

- Undergraduate sustainable energy engineering programs (e.g. BEng) with specializations in renewable energy systems or energy efficiency;
- Postgraduate sustainable energy engineering coursework programs (e.g. MEng) with specializations in renewable energy systems or energy efficiency;
- Postgraduate sustainable energy science/technical coursework programs (E.g. MSc) with specializations in energy efficiency and carbon management;
- Postgraduate sustainable energy humanities and social science coursework programs (e.g. MA) with a specialization in policy and enablers; and
- Conventional engineering, science and humanities programs with a sustainable energy focus or major.

Figure 18 shows the relationships between the 4 different program curriculum maps (not including majors in conventional degrees) with some units common to all programs and other units distinct to particular programs. Figure 19 shows a typical overarching curriculum framework map (in this case for the energy efficiency specialization) and Figure 20 shows the corresponding curriculum framework learning outcomes map. How to interpret these curriculum maps is explained in detail in Section 2 above.
Figure 19: A typical overarching curriculum frameworks map – energy efficiency.

Figure 20: A typical curriculum frameworks learning outcomes map - energy efficiency.
Feedback derived from the graduate and industry surveys in regard to the 5 key questions relating to program design and course delivery was considered when designing the curriculum frameworks. In particular this included:

- The balance of inter/multi-disciplinary knowledge vs specialist knowledge (e.g. engineering technical knowledge vs policy enablers knowledge etc.);
- The use of specialist undergraduate courses and programs versus embedding skills and knowledge into existing discipline training (e.g. a specialised undergraduate course versus embedding in an existing engineering degree); and
- Whether specialist programs should be offered at undergraduate or postgraduate level;

A number of well-known and respected sustainable energy programs are offered by international Universities. In order to ensure that any best practice or lessons learned from the development and offering of these programs was incorporated into the outcomes of this project a questionnaire survey was used. Email questionnaires and some follow up interviews (responder requested) were undertaken with key staff from a range of international institutions that have recognised sustainable energy programs. The survey sought information about their programs, their curriculum development and teaching/delivery approach as well as how they address the 5 key program design and course delivery questions.

The draft curriculum frameworks were refined at a workshop involving the project team members and were then trialed using the existing programs at the member Universities. The curriculum frameworks and associated cloths and knowledge taxonomies were then circulated to key stakeholders, including the external reference group for review and comment. The finalized 5 sets of curriculum frameworks are presented in detail in Section 2 and are available from the project website <http://www.murdoch.edu.au/projects/secfp/>.

The curriculum frameworks that have been developed and are reported in this document are seen as a work in progress and they will be refined and revised as feedback is received from the academics using them and other stakeholders. Any feedback should be provided via the contact details on the project website.

References


